

NEW SPECIES OF *DIPLOCARDIA* AND *ARGILOPHILUS*
(ANNELIDA: OLIGOCHAETA: MEGASCOLECIDAE)
FROM SOUTHERN CALIFORNIA

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Abstract.—Five new species of megascolecid earthworms, *Diplocardia californiana*, *D. woodi*, *D. montana*, *Argilophilus woodi*, and *A. margaritae* are described from material collected in various wildland habitats in the mountains neighboring the Los Angeles Basin. No other native earthworms were previously known from the region. The *Diplocardia* species are related to *D. keyesi*, known from Baja California, and all occur to the south of Los Angeles. Other *Argilophilus* are known from sites farther north; those described here are found to the north of the greater Los Angeles area. The northern limit of *Diplocardia* in California appears to be the San Gorgonio Pass. This may also be the southern limit of *Argilophilus* in California, but further collecting will be needed for confirmation.

It has been almost a century since anyone made an organized attempt to study terrestrial Oligochaeta in Southern California. The species presented here came to light as a result of the industriousness of Hulton B. "Hutch" Wood during his preliminary investigations of biotic factors affecting soils in the San Dimas Experimental Forest. Together we collected extensively in the mountains and wildlands surrounding the Los Angeles Basin. It may come as a surprise to learn that an area noted for a long dry period would support indigenous earthworms in unirrigated land. Though many sites were in riparian zones or adjacent to other sources of water, several were not so favored and not located at elevations where precipitation is abundant. A full account of the sites visited, their soils and vegetation, and the earthworm species encountered is in Wood & James (1993). Five species are new and are described here. Additional material was collected in early 1993, and further data on the new species were taken from these collections. There is also one more new species from the 1993 collections.

All specimens were obtained by digging and handsorting, and were killed in 50%

ethanol and fixed in 5% formalin. Examinations were conducted by dorsal dissection under a stereomicroscope with a drawing tube.

Diplocardia californiana, new species
Fig. 1A-C

Type material.—Holotype: USNM 169803, In grass/lupine meadow near vernal pool on Mesa de Colorado, Santa Rosa Plateau, near Temecula, Riverside Co., California, 5 Apr 1990, S. W. James, H. B. Wood, K. L. Olivier, collectors; Paratypes: USNM 169804, same locality as holotype.

Additional material.—In grass pasture of Love Valley, Cleveland National Forest, 22 Apr 1991, S. W. James and H. B. Wood, collectors; In grass among pines, Upper French Valley near Mt. Palomar Observatory, 22 Apr 1991, S. W. James and H. B. Wood, collectors; In grass adjacent to live oak grove, Falcon Camp, Cleveland National Forest, 24 Apr 1991, S. W. James and H. B. Wood, collectors; Long Canyon, Cleveland National Forest, near California Highway 74 in grassy area among oaks, 24 Apr 1991, S. W. James and H. B. Wood,

collectors; In grass/geranium mix and oak chaparral near Tenaja Creek, Cleveland National Forest, 24 Apr 1991, S. W. James and H. B. Wood, collectors. In grass/geranium mix and oak chaparral near Tenaja Creek, Cleveland National Forest, 6 Apr 1993, K. L. Olivier and H. B. Wood, collectors. Miller Mountain, in the bowl, basalt rock substrate with clay soil, grass, 15 Apr 1993, K. L. Olivier and R. Mees, collectors.

Description.—External characteristics: Dimensions 58–85 mm by 2.4–3.0 mm at segment xxx, 2.8–3.3 mm at vii; body cylindrical throughout, segments 106–164. Setae closely paired throughout; setal formula AA:AB:BC:CD = 3:1:4:1.3 at x, 3.5:1:3:1 at xxx, $DD > \frac{1}{2}$ circumference throughout. Prostomium epilobous to nearly tanylobous, segments with postsetal secondary annulus v, pre- and postsetal annuli vi–end, in x+ each third has tertiary annulus. Brown pigmentation present in i–v, vi, vii, denser dorsally; sometimes also present in male field area. Nephridiopores at D, first dorsal pore 9/10 or 10/11, spermathecal pores at leading edges of viii, ix lateral to A. Ovipores presetal median to A in xiv; male pores at 21/22; prostatic pores and penial setae at ends of seminal grooves in AB in xxi–xxiii. Clitellum xii–xxi, xxii, saddle-shaped; no genital markings (Fig. 1A).

Internal characteristics: Septa 5/6–11/12 muscular, greatest thickness at 8/9; 5/6 only faintly muscular. Alimentary canal with two gizzards in v, vi; appearing as one unit without substantial demarkation; esophagous with pebbly internal texture ix–xiii, low longitudinal folds 13/14–xviii, ventral esophageal ridge xi–xvii, esophagous valvular in xviii, xix, intestinal origin xx; typhlosole a simple fold originating over xxiii–xxv, height less than one tenth lumen diameter. No calciferous glands. Stomate meganephridia 2 per segment, exoic with duct entering body wall in CD, avesciculate, tubules in elongate flat coil over AD.

Vascular system with ventral trunk, single dorsal trunk, these connected by lateral

trunks in v–ix, latero-esophageal hearts in x–xii. Extra-esophageal vessel from pharyngeal glands, along ventral-lateral face of gizzard, ventral face of esophagous v–xiii, in xiii branching out to body wall of xiii–xx. Supra-esophageal vessel x–xiii.

Fan-shaped ovaries composed of long strings, with funnels in xiii; paired spermathecae in viii, ix, each an ovoid ampulla with sessile diverticulum composed of 3–6 internal lobes arranged in one row (Fig. 1B); ampulla under esophagous, ampulla long axis usually perpendicular to duct axis.

Male sexual system holandric, testes and funnels free in x, xi; acinous equal-sized seminal vesicles in ix, xii; vasa deferentia superficial, very thin, enter body wall at 21/22; tubular prostates with very short slightly muscular ducts, gland in several folds within segments of origin (xxi, xxiii); penial setal follicles just anterior to ducts. Penial setae 0.25–0.3 mm by 0.015 mm, nearly straight, gradually tapering to blunt tip (Fig. 1C); genital setae lacking.

Diagnosis.—*Diplocardia* with male field in xxi–xxiii.

Remarks.—Specimens from Love Valley, Tenaja Creek and Falcon Camp had abundant melanocytes in the linings of the body cavity, on blood vessels, nephridia, and other organs in the region xi–xxv. External pigmentation was slightly variable among sites, the darkest being those of Mesa de Colorado and the lightest coming from Falcon Camp and Upper French Valley. Oil droplets were abundant in the coeloms of worms from Long Canyon and Love Valley. Much of the material showed evidence of reduction in male functions. Seminal vesicles varied from partly filled to very small to rudimentary, even in fully clitellate individuals. Iridescence of male funnels was uncommon, and iridescence of spermathecal diverticula was seen only in the 1993 Tenaja Creek material. Prostates were quite small for *Diplocardia*, and penial setae were little more than straightened ambulatory setae. Some of the lack of male development could be season-

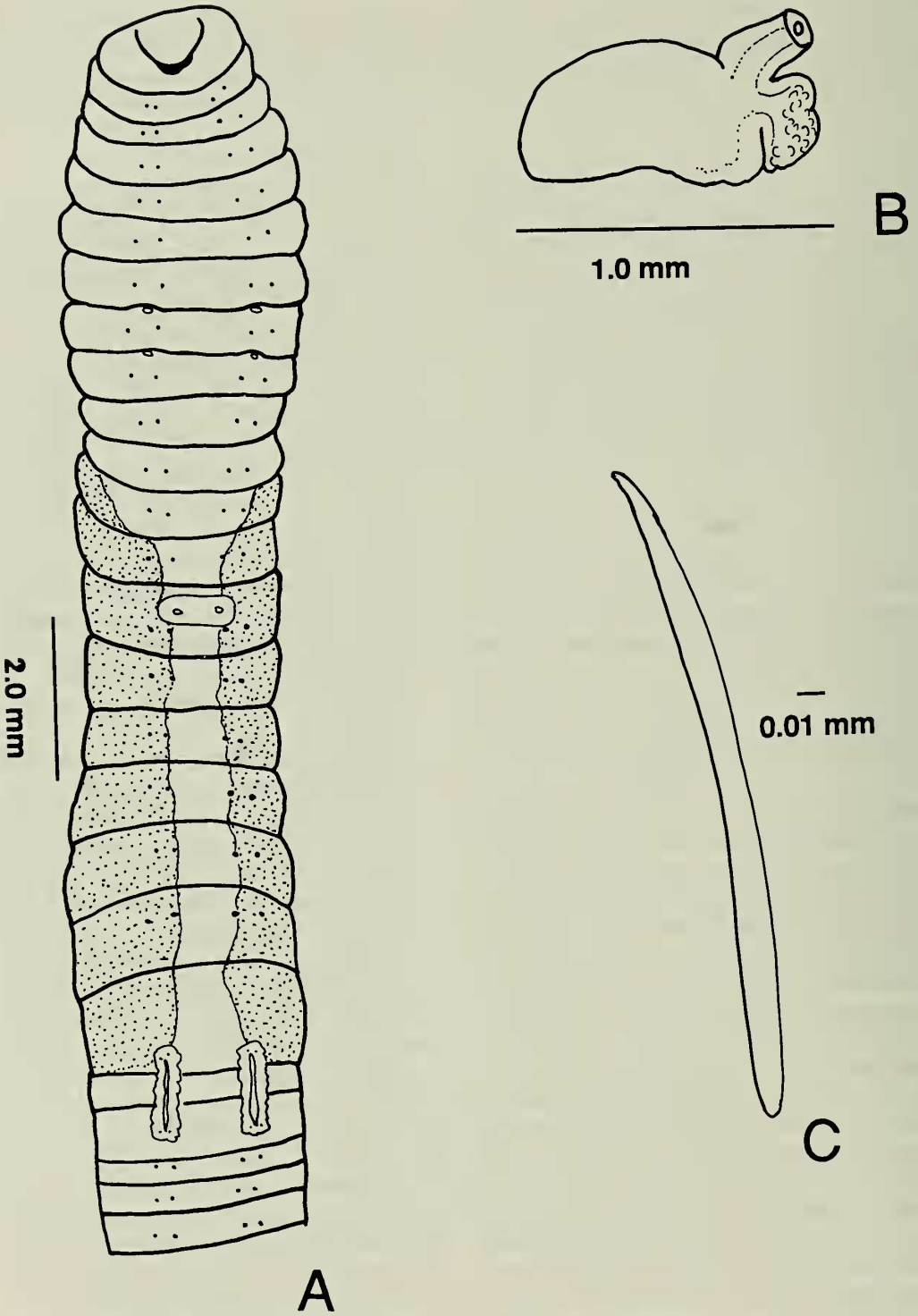


Fig. 1. *Diplocardia californiana*: A. ventral view, B. spermatheca, C. penial seta.

al, many of the sites having been at high elevations. However, all material examined was fully clitellate except the worms from Upper French Valley, the highest elevation site.

Diplocardia californiana is referred to as *Diplocardia* CA1 in Wood & James (1993).

Diplocardia keyesi Eisen, 1900 has the male field in xx–xxii. This would place it as the nearest relative of the new *Diplocardia* described here. *Diplocardia keyesi* is known only from a single location in northern Baja California, near Ensenada. The location of the male field or male pores is usually very conservative in earthworms, but is quite variable in *Diplocardia*.

Diplocardia woodi, new species

Fig. 2A, 2B

Type material.—Holotype: USNM 169806, Mesa de Burro, Santa Rosa Plateau, Riverside Co., California. 1 Apr 1993, K. L. Olivier, collector; Paratypes: USNM 169807, same locality as holotype.

Additional material.—Mesa de Burro, Santa Rosa Plateau, Riverside Co., California. 5 Apr 1990, S. W. James, H. B. Wood and K. L. Olivier, collectors.

Description.—External characteristics: Dimensions 63–78 mm by 2.7–2.9 mm at segment xxx, 3.2 mm at ix; body cylindrical throughout, segments 134–153. Pigmentation lacking or present as slight rings of brown pigment at segmental equators of some or all of ii–v. Setae closely paired throughout; setal formula AA:AB:BC:CD = 3.5:1:3:1.3 at x, 4:1:3.5:1.3 at xxx, DD > ½ circumference throughout.

Prostomium epilobous, segments with postsetal secondary annulus vi–vii, pre- and postsetal annuli viii–end, in xxii+ postsetal third has tertiary annulus. Nephridiopores not seen, first dorsal pore 9/10 or 10/11, spermathecal pores at leading edges of viii, ix lateral to A. Ovipores presetal median to

A in xiv; male pores at 21/22; prostatic pores and penial setae at ends of seminal grooves in AB in xxi–xxiii. Clitellum saddle-shaped, interrupted at mid-ventral line, xii–xxi; no genital markings (Fig. 2A).

Internal characteristics: Septa 6/7–11/12 muscular, greatest thickness at 8/9; 13/14 only faintly muscular. Alimentary canal with two gizzards in v, vi; appearing as one unit with thin region at 5/6; esophagous with pebbly internal texture ix–xviii, ventral esophageal ridge 12–18, valvular in xix, intestinal origin xx; typhlosole simple fold originating over xxiii–xxv, height one fifth lumen diameter. No calciferous glands. Stomate meganephridia 2 per segment, exoic with duct entering body wall in CD, ave-siculate, tubules in elongate flat coil over BD.

Vascular system with ventral trunk, single dorsal trunk, these connected by lateral trunks in v–ix, latero-esophageal hearts in x–xii. Extra-esophageal vessel from pharyngeal glands, along ventral-lateral face of gizzard, ventral face of esophagous v–xiii, in xiii branching out to body wall of xiii–xx. Supra-esophageal vessel ix–or x–xiii.

Fan-shaped ovaries composed of long strings, with funnels in xiii; paired spermathecae in viii, ix, each an ovoid ampulla with sessile diverticulum composed of 1–3 internal lobes (Fig. 2B).

Male sexual system holandric, testes and funnels free in x, xi; seminal vesicles in ix, xii, both quite small; vasa deferentia superficial, very thin, enter body wall at 21/22; tubular prostates with very short slender ducts less than one-tenth gland length, gland in several folds within segments of origin (xxi, xxiii); penial setal follicles just anterior to ducts, penial setae not enlarged (4) or lacking (1); genital setae lacking.

Diagnosis.—*Diplocardia* with male field in xxi–xxiii, and distinguished from *D. californiana* by the greater height of the typhlosole, smaller nephridia, fewer lobes of the spermathecal diverticulum, lack of mus-

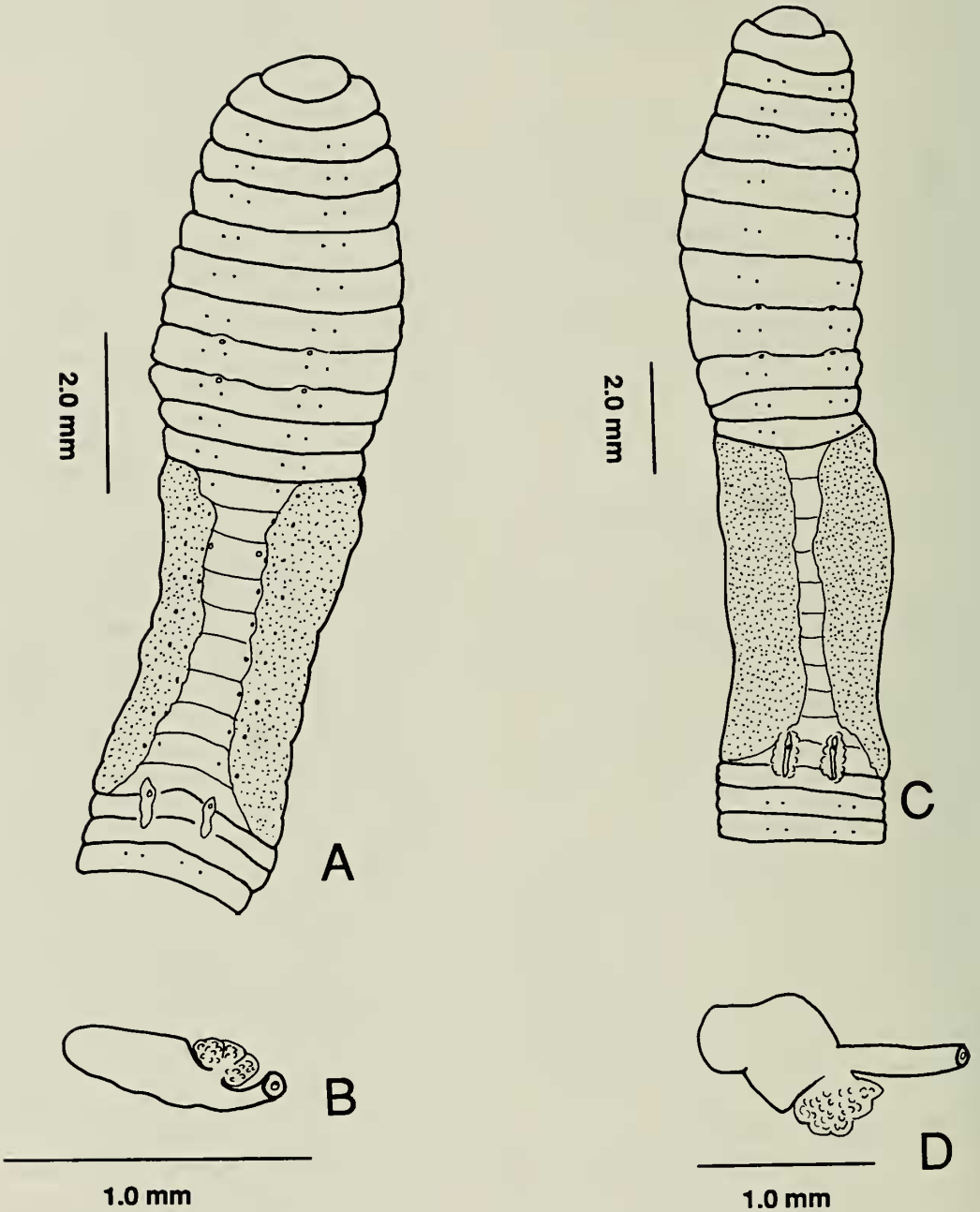


Fig. 2. *Diplocardia woodi*: A. ventral view, B. spermatheca. *Diplocardia montana*: C. ventral view, D. spermatheca.

cularity of prostatic ducts, and lack of development of penial setae.

Remarks.—Iridescence of the male funnels was detected on one individual from the 1993 material, though coagulum was present in segments x and xi of all material examined. Spermathecal diverticula of the 1993 material were iridescent, but those of the 1990 material were not. The species is named after Hulton B. Wood. It is referred to as “*Diplocardia CA2*” in Wood & James (1993).

Diplocardia montana, new species

Fig. 2C, 2D

Type material.—Holotype USNM 169805, Miller Mountain, San Diego Co. California, top end of jeep trail, 900 m elev., clay loam soil and grass; 15 Apr 1993, K. L. Olivier and R. Mees, collectors.

Description.—External characteristics: Dimensions 103 mm by 3.5 mm at segment xxx, 4 mm at ix; body cylindrical throughout, segments 152. Pigmentation present as slight rings of brown pigment at segmental equators on ii–viii. Setae closely paired throughout; setal formula AA:AB:BC:CD = 4:1.3:4:1 at x, 3:1:4:1.2 at xxx, DD > ½ circumference throughout. Prostomium probolous, segments with postsetal secondary annulus vi–vii, pre- and postsetal annuli viii–end, in xxii+ postsetal third has tertiary annulus. Nephridiopores not seen, first dorsal pore 10/11, spermathecal pores on small bumps at leading edges of viii, ix in A. Ovipores presetal median to A in xiv; male pores at 21/22; prostatic pores at ends of seminal grooves in AB in xxi–xxiii. Clitellum saddle-shaped, interrupted at mid-ventral line, xii–xxii; no genital markings (Fig. 2C).

Internal characteristics: Septa 6/7–11/12 muscular, greatest thickness at 8/9; 12/13 only faintly muscular. Alimentary canal with two gizzards in v, vi; appearing as one unit

with thin region at 5/6; esophagous with pebbly internal texture ix–xviii, paired ventral esophageal ridges xiii–xviii, valvular in xix, intestinal origin xx; typhlosole simple fold originating 22/23, height one tenth lumen diameter or less. No calciferous glands. Stomate meganephridia 2 per segment, exoic with duct entering body wall in CD, avesculate, tubules in elongate flat coil over BD.

Vascular system with ventral trunk, single dorsal trunk, these connected by lateral trunks in v–ix, latero-esophageal hearts in x–xii. Extra-esophageal vessel from pharyngeal glands, along ventral-lateral face of gizzard, ventral face of esophagous v–xiii, in xiii branching out to body wall of xiii–xx. Ventral esophageal ridges contain blood vessels connected to extra-esophageals. Supra-esophageal vessel x–xiii.

Fan-shaped ovaries composed of long strings, with funnels in xiii; paired spermathecae in viii, ix, each an ovoid ampulla with sessile diverticulum composed of 1–3 internal lobes (Fig. 2D).

Male sexual system metandric, testes and funnels free in xi; seminal vesicles in xii; vasa deferentia superficial, very thin, enter body wall at 21/22; tubular prostates with very short slender ducts so that prostates are nearly sessile, gland in several folds within segments of origin (xxi, xxiii) or one adjacent segment; penial setal follicles just anterior to ducts, penial setae vestigial; genital setae lacking.

Diagnosis.—*Diplocardia* with metandric reduction of the male gonads, male field in xxi–xxiii.

Remarks.—Apart from the metandric condition, *D. montana* is very similar to its southern California congeners. However, its one pair of male funnels and its spermathecal diverticula were iridescent, and there was no other evidence of reduction of male functions. It is also somewhat larger than the other species. So far it is the only known metandric *Diplocardia*.

Argilophilus woodi, new species

Fig. 3A–C

Type material.—Holotype, USNM 169799. Type locality: in oaks and sagebrush, 1300 m elev., near milepost 41.50, California Hwy. 33, Ventura Co. California, 4 Apr 1990, S. W. James and H. B. Wood, collectors. Paratypes (USNM 169800) from same locality, three adults, 4 Apr 1990, S. W. James and H. B. Wood, collectors.

Description.—External characteristics: Dimensions 51–58 mm by 3.5–4 mm (strongly contracted), width at segment xxx, body cylindrical throughout, segments 125–140. Pigmentation lacking. Setae ab closely paired throughout; setal formula AA:AB:BC:CD = 3.5:1:2.5:2.5 at xxx, DD > ½ circumference throughout. Prostomium epilobous, segments with postsetal secondary annulus vi–ix, pre- and postsetal annuli x–xii. Nephridiopores not seen, first apparent dorsal pore 18/19, but dorsal pores merely thin spots in body wall, few if any actually open; spermathecal pores at leading edges of viii, ix at B. Ovipores presetal median to A in xiv; male pores in xviii on small papillae; penial setae emerge from papillae in xviii. Clitellum annular xiii–xviii, no genital markings (Fig. 3A).

Internal characteristics: Septa 6/7–13/14 muscular, greatest thickness 8/9–11/12; 13/14 only faintly muscular. Alimentary canal with gizzard in vi; esophagous with pebbly internal texture x–xiv, low longitudinal folds xv; ventral esophageal ridge x–xv, valvular in xvi, intestinal origin xvii, no caecum; typhlosole simple fold originating over 20/21–xxv, terminates in region lxxxiv–ci, height one-fourth lumen diameter. No calciferous glands. Stomate meganephridia 2 per segment, exoic with duct entering body wall in CD, avesculate, tubules in elongate flat coil over BC.

Vascular system with ventral trunk, single dorsal trunk, these connected by lateral trunks in vi–x, esophageal hearts in xi–xiii. Lateral trunk of vi with branch to gizzard, in v trunk from dorsal vessel to gizzard.

Extra-esophageal vessel present but not traceable. Supra-esophageal vessel x–xiii.

Fan-shaped ovaries composed of long strings, with funnels in xiii; paired spermathecae in viii, ix, each an ovoid ampulla with one or two sessile hemispherical diverticula (Fig. 3B).

Male sexual system holandric, testes and funnels free in x, xi; seminal vesicles in xi, xii, that of xii twice size of seminal vesicle in xi; vasa deferentia superficial, enter distal end of tubular prostate glands in xviii; prostates with slender ducts about one quarter length of glandular portion; penial setal follicles just anterior to ducts, penial setae bowed, 540 × 12 microns (Fig. 3C).

Diagnosis.—*Argilophilus* with last hearts in xiii, gizzard in vi, no genital markings or papillae other than those of male pores.

Remarks.—*Argilophilus woodi* is most similar to the new species described below, and otherwise seems close to *A. sierrae* Michaelsen, 1921 based on somatic characters. The material used to describe *A. sierrae* was immature, so comparisons are difficult. However, that species does have much larger and more ornamented penial setae, adiverticulate spermathecae, a midventral papilla in xviii, and only one pair of seminal vesicles (Michaelsen 1921). *Argilophilus woodi* differs from previously published species in having the diagnostic combination given above. The species *A. panuliris* MacNab & McKey-Fender, 1959, *A. marmoratus* Eisen, 1893, *A. papillifer* Eisen, 1893 and *A. collinus* Eisen, 1900 all have the last hearts in xii (except *A. papillifer* which also has last hearts in xiii) and gizzard in v and vi (the first) or in v only (the last three) (Eisen 1894, 1900; Gates 1941, 1962, 1977; MacNab & McKey-Fender 1959; McKey-Fender 1970). There are other differences, such as the clitellae of most of these species being saddle-shaped, and there being genital markings on some part of the body in each. *Argilophilus hammondi* McKey-Fender, 1970 has its gizzard in v and an earlier intestinal origin than *A. woodi*, a saddle-shaped clitellum, several sets of

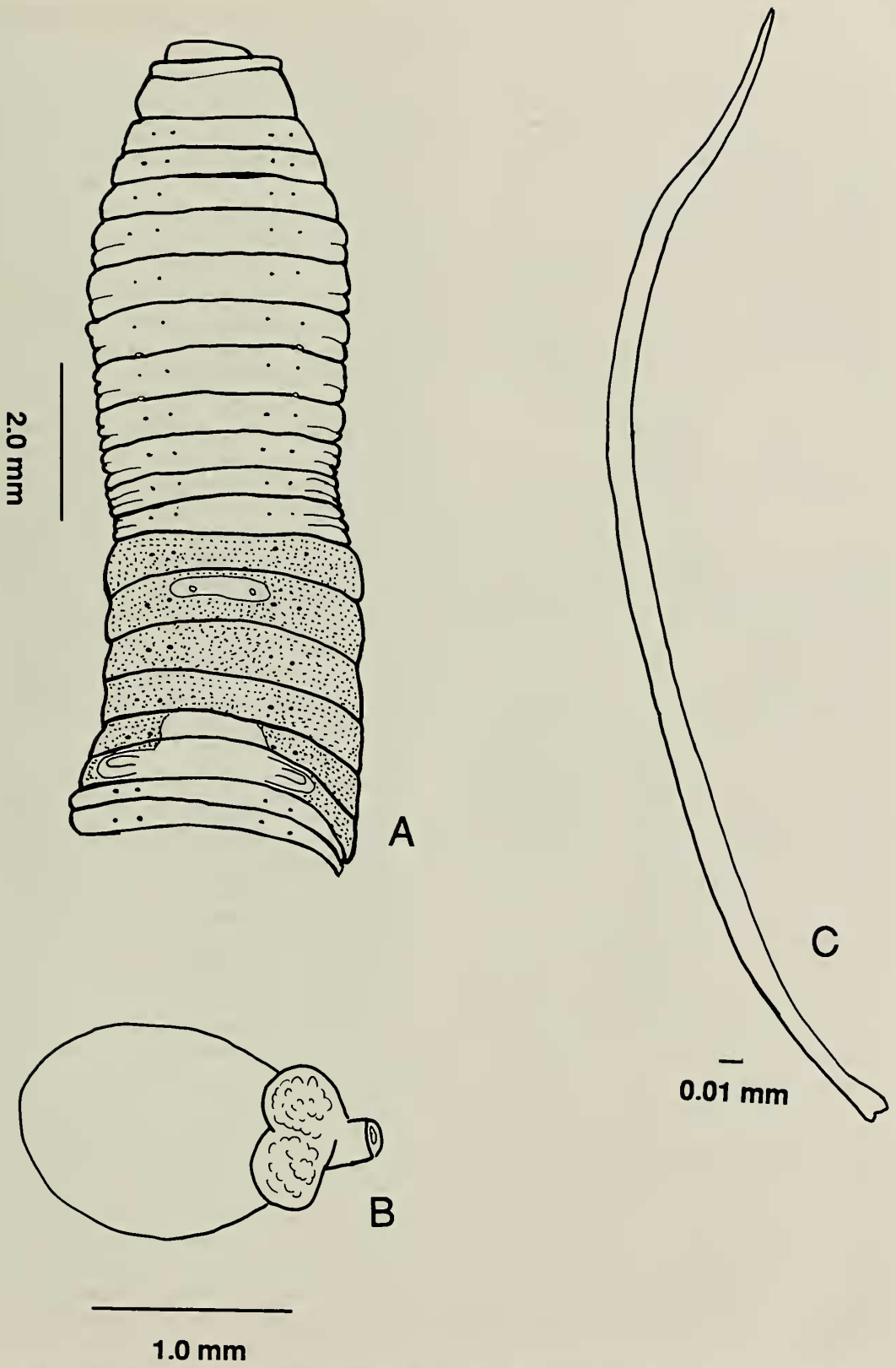


Fig. 3. *Argilophilus woodi*: A. ventral view, B. spermatheca, C. penial seta.

paired genital markings, a longer typhlosole and longer penial setae (McKey-Fender 1970). *Argilophilus garloughi* Smith, 1937 has last hearts in xiii but also has calciferous lamellae, a later intestinal origin and the gizzard in v (Smith 1937).

The species is named for Hulton B. Wood, whose interest in earthworms led to its discovery, and who was the first to come up with a specimen in a seemingly unlikely spot for earthworms. It is referred to as "*Argilophilus 1*" in Wood & James (1993).

Argilophilus margaritae, new species
Fig. 4A–C

Type material.—Holotype USNM 169801 and Paratypes USNM 169802, in canyon live oak and bay forest, Sec. 13 R12W, T2N along Forest Service Road 2N24, 2 Apr 1990, S. W. James and H. B. Wood, collectors.

Additional material.—Oak-sycamore riparian forest, West Fork San Gabriel River, 2 Apr 1990, S. W. James and H. B. Wood, collectors. Canyon live oaks on north-facing slope of San Gabriel River valley, Forest Service Road 2N24, 2 Apr 1990, S. W. James and H. B. Wood, collectors. Oak and Coulter Pine with grass understorey, 1670 m. elev., 5 km west of Running Springs on California Hwy. 330, 23 Apr 1991, S. W. James and H. B. Wood, collectors. Ponderosa pine-oak forest with grass understorey at milepost 33.93 on California Hwy. 138 east of Crestline, 23 Apr 1991, S. W. James and H. B. Wood, collectors.

Description.—External characteristics: Dimensions 45–78 mm by 4–5 mm, width at segment xxx, generally strongly contracted during fixation; body cylindrical throughout, segments 124–148. Pigmentation lacking. Setae ab closely paired throughout; setal formula AA:AB:BC:CD = 3.7:1:3:2.3 at xxx, $DD > \frac{1}{2}$ circumference throughout. Prostomium epilobous, seg-

ments with postsetal secondary annulus vi–x, pre- and postsetal annuli x–xii. Nephridiopores not seen, first dorsal pore 12/13–19/20 but dorsal pores mostly merely thin spots in body wall, few actually open; spermathecal pores at leading edges of viii, ix at B. Ovipores presetal median to A in xiv; male pores in xviii. Clitellum xiii–xviii, annular only over xiii–xiv, genital marking at 9/10 broad oval intersegmental papilla in BB or genital markings lacking (Fig. 4A).

Internal characteristics: Septa 6/7–11/12 muscular, greatest thickness 8/9–10/11; 12/13 only faintly muscular. Alimentary canal with gizzard in vi; esophagous with pebbly internal texture xi–xiii, low longitudinal folds xiv–xv; sometimes a ventral esophageal ridge xii–xiv, valvular in xvi, intestinal origin xvii or one-half xvii, no caecum; typhlosole simple fold originating over 20/21–xxiv,xxv, terminates li–lvii; height one third lumen diameter or less. No calciferous glands. Stomate meganephridia 2 per segment, exoic with duct entering body wall in CD, avesculate, tubules in rounded flat coil over BC.

Vascular system with ventral trunk, single dorsal trunk, these connected by lateral trunks in vi–x, esophageal hearts in xi–xiii. Lateral trunk of vi with branch to gizzard, in v trunk from dorsal vessel to gizzard. Extra-esophageal vessel from under pharynx, along ventral-lateral face of gizzard, ventral face of esophagous iv–xiii, in xiii branching out to body wall of xiii–xviii. Supra-esophageal vessel xi–xiii, with lateral bulges to points of attachment of hearts.

Fan-shaped ovaries composed of long strings, with funnels in xiii; paired spermathecae in viii, ix, each an ovoid ampulla with 2–3 lobed sessile diverticulum broadly attached to spermathecal duct (Fig. 4B).

Male sexual system holandric, testes and funnels free in x, xi; seminal vesicles in xi, xii, that of xii slightly larger; vasa deferentia superficial, enter distal ends of tubular prostatic glands in xviii; prostates with slender

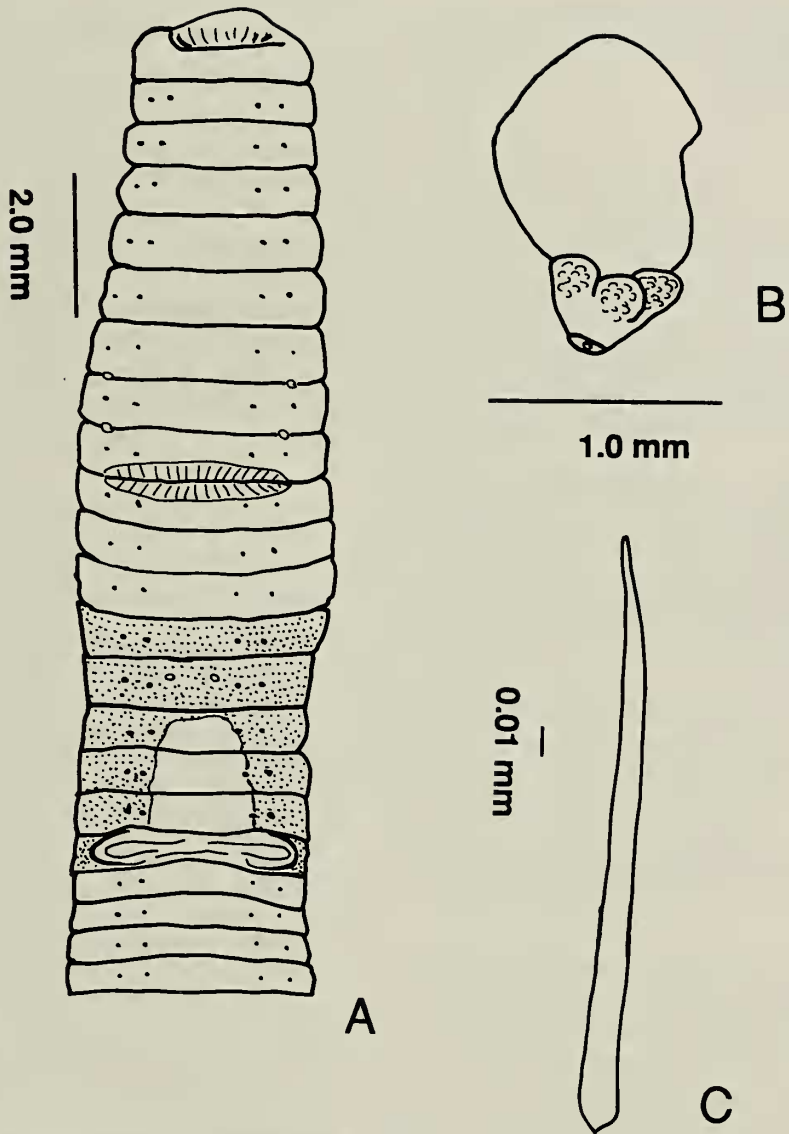


Fig. 4. *Argilophilus margaritae*: A. ventral view, B. spermatheca, C. penial seta.

ducts about one tenth length of glandular portion or shorter; penial setae absent or setae ab of xviii not differentiated from ambulatory setae (Fig. 4C).

Diagnosis.—*Argilophilus* with last hearts in xiii, gizzard in vi, no penial setae, one genital marking at 9/10 or none, partially annular clitellum.

Remarks.—This species differs from its previously published congeners in the same ways as *A. woodi*, with the sometime exception of the presence of a genital marking. It differs from *A. woodi* in having a lesser extent of annularity in the clitellum, a shorter typhlosole, no penial setae, and a prostatic duct that is shorter relative to the length of the prostate gland. The configuration of the spermathecal diverticula is also different.

Argilophilus margaritae, under the name "*Argilophilus 2*" was found in a variety of habitats and soil types, ranging from fine- to coarse-textured (Wood & James 1993).

The species name is the genitive case Latin equivalent of the name of the author's older daughter.

In Wood & James (1993) we noted that *Argilophilus* species were absent from the region south of 34°N latitude, coinciding with San Geronio Pass. This low desert and the lowlands to the west (presently the Los Angeles metropolitan area) may have presented a barrier to the dispersal of earthworms.

Diplocardia species were found to the south of this boundary, except for the San Jacinto Peak region which appears not to harbor any native earthworms. Exotic Lumbricidae are present there as there are in many of the sites sampled, so there is nothing inherently inimical to earthworms about the highlands around San Jacinto Peak. However, south of the boundary we collected one immature specimen of a megascolecoid worm with a single gizzard in one segment, greatly resembling a young *Argilophilus*. Reserving judgment on that record

until more material can be obtained, the range of *Argilophilus* is now extended south to 34°N latitude.

Acknowledgments

This research was supported by a grant from the United States Department of Agriculture Forest Service to Hulton B. Wood and the author. Dr. Wood and his staff selected field sites and arranged cooperation with numerous Forest Service personnel and with The Nature Conservancy. Without his interest in earthworms and perseverance this research would not have been done. Jessica Malloy assisted with preliminary identification and cataloguing of collections.

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